The change character of monsoon rainband over Heilongjiang Province for the past 40 years

LI Jin-rong and LIU Bin-hui

Northeast Forestry University, Harbin 150040, P. R, China

Abstract: Precipitation in Heilongjiang Province of China increased slightly from 1960 to 2000. Adopting the method proposed by Arthur N. Samel, we separated monsoon rainband rain and calculated the initial and final date of monsoon rainband of each year and each station. For the period of 1960–2000, the change of annual precipitation in Heilongjiang Province, with an increasing trend of 2.229 mm per decade, is not significant; the duration and total monsoon rain decreased significantly, with a decreasing trend of -6.9 day per decade and -17.5 mm per decade separately. That change comes from early leaving date of summer monsoon rainband for the period of 1960-1975 and later arriving date of summer monsoon rainband for the period of 1990-2000. The weakening of summer monsoon makes its contribution to the annual precipitation decreased significantly, with a decreasing trend of 4.4 % per decade.

Keywords: Precipitation; Monsoon rainband; Summer monsoon; Heilongjiang Province; China;

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Introduction

The climate of Asia is strongly controlled by the monsoon system. In particular, the water resources in East Asian countries depend largely on the precipitation during summer rainy season, which is strongly controlled by the East Asian monsoon system. In Northeast Asia, which has large areas of farm land, monsoon rain condition controls the productivity of the crops. The summer monsoon rainfall over East Asia exhibits diverse regional characteristics, which are known as different names in different countries: Mei Yu in China, Baiu in Japan, and Changma in Korea. The monsoon rainbands associated with these regional features undergo abrupt changes and appear at different phases of the monsoon cycle. Therefore, the variations of regional rainbands are linked to large-scale monsoon changes. However the linkage is not well documented at present. Although the Asian monsoon is a complex phenomenon involving many timescales of variations, the seasonal variation is most distinctive. Thus an important task of monsoon research is to define the variation of the basic state—that is, the climatological seasonal cycle. An interesting aspect of climatological monsoon variations is the existence of intraseasonal variation superimposed on the smoother seasonal cycle. Several studies have suggested that a phase-locked intraseasonal variation controls the climatological onset date of regional rainy season over much of the Asian monsoon region (Kang 1999).

The major findings made in recent two decades include several following points: (1)The seasonal march of the East Asian summer monsoon displays a distinct stepwise northward and northeastward advance, with two stepwise northward and northeastward advance, with two abrupt northward jumps and three stationary periods. The monsoon rain commences over the region from the Indochina Peninsula-the SCS-Philippines during the period from early May to mid-May, then it extends abruptly to the Yangtze River Basin, and western and southern Japan, and the southwestern Philippine Sea in early to mid-June and finally penetrates to North China, Korea and part of Japan, and the topical western West Pacific. (2) After the onset of the Asian summer monsoon, the moisture transport coming from Indochina Peninsula and the South China Sea plays a crucial ''switch'' role in moisture supply for precipitation in East Asia, thus leading to a dramatic change in climate regime in East Asia and even more remote areas through teleconnection. The East Asian summer monsoon and related seasonal rain belts assumes significant variability at intraseasonal, interannual and interdecadal time scales. Their interaction, i.e., phase locking and in-phase or out-phase superimposing, can to a greater extent control the behaviors of the East Asian summer monsoon and produce unique rythem and singularities (Ding 2005). Based on studies mainly by Chinese meteorologists over many years, it has been found that many differences exist between the monsoon circulation over India and that over East Asia. This fact suggests that the structure and main components of the monsoon system over East Asia is likely to be independent of the Indian monsoon system.

The climate of the later half of 20th century underwent fast change in many aspects. It can not be solely attributed to natural fluctuate. Human activity play important role in the cause of change (Eastering 1997). For China, air temperature began to increase in the late of 1970s, there exist region and daily difference (Liu *et al*. 2004 a), 1998 is the hottest year of last century; pan evaporation decreased in China from 1955 to 2000 (Liu *et al.* 2004b); precipitation in China increased by 2% over that period while the frequency of precipitation events decreased by 10% (Liu *et al*. 2005). Whether these changes have influence on the character of monsoon rainband, especially for the fast temperature change period between 1990 and 2000 is unknown. In this paper, we present an analysis of the changing character of monsoon rainband in Heilongjiang Province on an annual basis using the method created by Arthur N. Samel. Our result can improve our understanding the temperature change influence on the character of monsoon for the most important agricultural province of China.

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Biography: LI Jin-Rong (1968-), Female, Lecture in Northeast Forestry University, Harbin150040, P. R, China

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Data

The data included daily precipitation measurements from 16 stations for the period of 1951–2000. Table 1 shows the name, longitude, latitude and altitude of station. The stations were well distributed across Heilongjiang Province (Figure 1). Measurements of all the climate stations in China were made using the same standards and instrumentation, ensuring the homogeneity of data quality.

Table 1. Longitude, latitude and altitude of the 16 meteorological observation stations used in these study

Station	Longitude	Latitude	Altitude (m)
Mohe	122°22′	53°28′	296
Huma	126°39′	51°43′	177.4
Nenjiang	125°14′	49°10′	242.2
Keshan	125°53′	48°03′	234.6
Qiqihaer	123°55′	47°23′	145.9
Hailun	126°58′	47°26′	239.2
Tonghe	128°44′	45°58′	108.6
Fujin	131°59′	47°14′	64.2
Anda	125°19′	46°23′	149.3
Jiamusi	130°17′	46°49′	81.2
Harbin	126°46′	45°45′	142.3
Jixi	130°57′	45°17′	233.6
Shangzhi	127°58′	45°13′	189.7
Mudanjiang	129°36′	44°34′	241.4
Heihe	127°27′	50°15′	166.4
Shuifenhe	131°09′	44°23′	496.7

Fig. 1. Location of 16 observation stations in Heilongjiang Province where 1960–2000 daily precipitation data are analyzed

The consistency and completeness of the data set was important in this study of monsoon rainband. Precipitation differs from other climate variables such as temperature, which change gradually from hour to hour and day to day. Missing data for such other variables can be estimated by means such as stepwise regression (Liu *et al.* 2004a), but this would be inappropriate for precipitation because most precipitation events are more variable in time. Instead, we took strict measures to exclude stations and years with missing data from our analysis. Most of the cases where stations' data was missing for three or more consecutive days occurred before 1960, so in this study we consider only the period of 1960 to 2000 by excluding the early part of the dataset from the analysis. Records from these stations in the study period are over 99.99% complete, with only 4 missing observations from 3 stations. No single station accounted for more than four missing observations or two consecutive missing observations. Therefore, the missing data should have minimal impact on our results.

Analysis procedures

We defined the initial, final date of rainband and the analyze procedure following the method created by Arthur N. Samel (Samel 1999). Precipitation at each location is normalized by the mean annual total for that station such that daily values are given as a percentage of the annual mean. This normalization eliminates geographical differences in annual average amount such that the value at all locations becomes 1.00. For each station, rainfall is defined to be heavy when the daily amount exceeds 1.5% of the annual average for that location. A 25-day moving window was then applied to all yearly time series between the first and last days when rainfall exceeded 1.5%. Heavy precipitation was defined to be persistent and thus, identified with the rainband, when the 1.5% threshold is exceeded six or more times in a 25-day period. Finally, frequency distributions of the consecutive number of days with zero and nonzero precipitation indicated that the hydrologic cycle over China rarely remains active or dormant for a period that exceeds five days. Hence, a minimum of five consecutive days with no measurable rainfall was chosen as the requirement used to identify the initiation and withdrawal of rainband precipitation at a specific location. Rainband initial (final) dates are defined to immediately follow (precede) a minimum period of five consecutive days with no measurable precipitation. A semiobjective analysis based on the above definitions and rainband climatology is then applied to the time series to determine annual initial and final dates.

Results and discussion

Precipitation appears to have increased slightly in Heilongjiang Province (HLJ) over the period of 1960–2000 (Figure 2). For the period of 1960–2000, the change of annual precipitation, with increasing trend of 2.229 mm per decade, is not statistically significant (α=0.10). The result is similar as former results for the same period (Liu *et al.* 2005). The overall precipitation does not change much over the past 40 years in HLJ. The annual total can not reveal the character of the precipitation condition, two region with similar annual precipitation, but the yearly sum may come from differ precipitation intensity distribution and precipitation frequency. It is also true for same region in differ year. Therefore, for a region, the annual total with no change do not means that condition is unchanged.

We calculate the initial date of monsoon rainband using the semiobjective analyzing method created by Samel (1999). The result shows that from 1960–2000, the initial date of monsoon rainband in HLJ with increasing trend of 2.4 day per decade, the change is statistically significant(α=0.10), and the increase is most obvious in the last decade of last century (Figure 3). Most

climate model shows that the water cycle will intensify with a warmer climate (Frei 1998). Summer monsoon rainband arrived to HLJ Province later in the later half of 20th century, in the mean time, temperature increase very fast in the same period (Liu 2004a), and the observation calculation seems do not support the climate model.

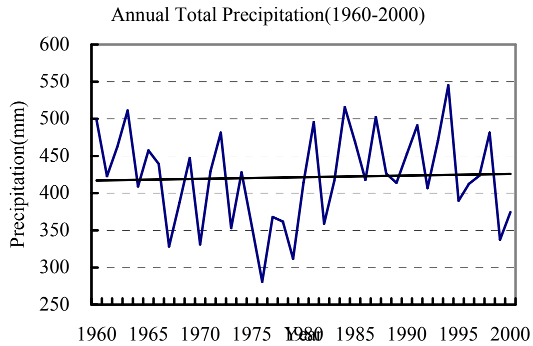

Fig. 2 Annual total precipitation in Heilongjang Province.
The straight line denotes the linear trend.

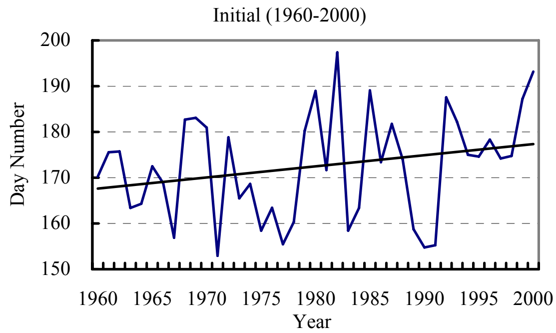

Fig. 3 Monsoon initial date in Heilongjiang Province.
The straight line denotes the linear trend.

The final date of monsoon rainband in HLJ Province for the period of 1960–2000 reveals decreasing trend of 4.5 day per decade, and the change is statistically significant(α=0.10) (Figure 4). It means that summer monsoon rainband leave HLJ Province early and the decrease is most obvious between 1960 and 1975.

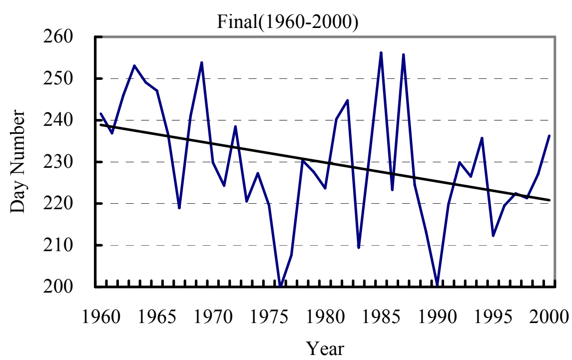

Fig .4 Monsoon final date in Heilongjiang Province.
The straight line denotes the linear trend.

Summer monsoon rainband arrived in HLJ Province later and leave early, so the duration of summer monsoon rainband stay in HLJ becomes shorter. The length of monsoon rainband in HLJ Province for the period of 1960–2000 reveals decreasing trend of -6.9 day per decade, and the change is statistically significant (α=0.10) (Figure 5). The decrease can be separated into two periods: one is between 1960–1975, another is between 1990–2000. Ssummer monsoon rainband do not changed much for the period between 1975and 1990. Summer monsoon that leave earlier and arrived later have contributed to the change character separately. From the arriving, leaving date and length of summer monsoon rainband, we can get the result of monsoon been weakened in HLJ. There must exist some mechanism that produce the change, so need further research on it. Also we do not know the mechanism of the change, the weakening of monsoon could have influence on the most north province of China, not only in climate condition, but also in its economy.

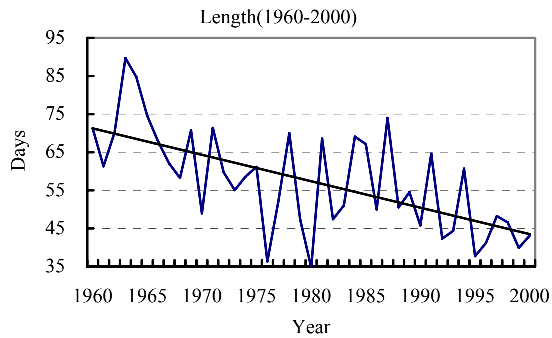

Fig. 5 Monsoon duration in HeiLongJiang province, in days
The straight line denotes the linear trend.

The change character of total monsoon rain could further support the view of weakening of summer monsoon. The total rain duration summer monsoon in HLJ Province for the period of 1960 to 2000 reveals decreasing trend of –17.5 mm per decade. The change is statistically significant (α=0.10) (Figure 6). It reveals that total water transported to HLJ by monsoon has decreased. The productivity of crops in HLJ depends on rain, especially summer monsoon, so the decreasing trend of summer monsoon duration, and rain could not be a piece of good news. The decreasing trend will continue or just a temporary phenomenon is unknown.

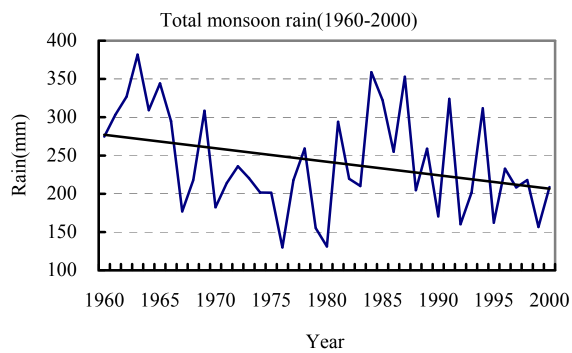

Fig. 6 Total monsoon rain in Heilongjiang Province, in mm.
The straight line denotes the linear trend.

With decreasing trend of monsoon rainfall and unchanged annual total precipitation, we can get the result that the ratio between monsoon rain and annual precipitation in HLJ should have decreased. The calculation supported such reference, the ratio between monsoon rain and annual precipitation in HLJ province for the period of 1960–2000 reveals decreasing trend of -4.4 % per decade, the change is statistically significant(α=0.10) (Figure 7). It means the summer monsoon's contribution to the water condition of HLJ province has decreased, from highest 75% to 55% for the period of 1960–2000. So also the water condition in HLJ is unchanged for the past 40 years, the distribution of water inter-season has changed, summer monsoon season becomes drier and the other time becomes wetter, further research is needed for the mechanism and the influence of that change.

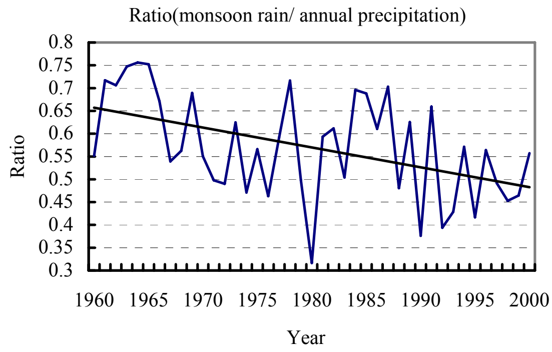

Fig. 7. The ratio between total monsoon rain and annual precipitation in Heilongjiang Province.
The straight line denotes the linear trend.

Conclusions

This analysis demonstrated the changing character of monsoon rainband in HLJ province for the period of 1960–2000. Adopting the method proposed by Samel (1999), we separated monsoon rainband rain and calculated each year each station's initial and final date of monsoon rainband. Here we summarize our findings: the annual precipitation in HLJ Province with increasing trend of 2.229 mm per decade for the period of 1960–2000, the change is not significant; the duration and total monsoon rain decreased significantly, with decreasing trend of -6.9 day per decade and -17.5 mm per decade separately. That change comes from early leaving date of summer monsoon rainband for the period of 1960–1975 and later arriving date of summer monsoon rainband for the period of 1990–2000. The weakening of summer monsoon makes its contribution to the annual precipitation has decreased significantly, the decreasing rate is -4.4 % per decade. Further research is needed for analyze the mechanism of that change and effects of that change on economy and environment.

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